DOCUMENT RESUME

ED 028 056 24 SE 002 972

By-Korn, Harold A.; Wise, Lauress L.

Techniques for Evaluating the Learning Process in Engineering Education.

Stanford Univ., Calif.
Bureau No-BR-5-8200
Pub Date Jul 66
Note-19p.
EDRS Price MF-$0.25 HC-$1.05
Descriptors-*Academic Achievement, *College Science, Educational Objectives, *Engineering Education, *Evaluation, Grading, Learning, Motivation, *Physical Sciences, Problem Solving, Student Characteristics

It is felt that an important source of information in engineering education is ofte n overlooked - the differential impact of the learning process on each student. Currently, the only measure of this sort is the final grade. This research involved (1) developing techniques for assessing various aspects of a student's class performance, and (2) examination of the usefulness of the traditional grade point average. Two different attacks on the problem were used--(1) multivariate correlational study of grading practices, and (2) development of both strategies and devices for observing and evaluating engineering courses. (DH)

BR-5-8200
PA 24

TECHNIQUES FOR EVALUATING THE LEARNING PROCESS IN ENGINEERING EDUCATION

HAROLD A. KORN and LAURESS L. WISE

STANFORD UNIVERSITY
STANFORD, CALIFORNIA

S - 278

JULY 1965 to JULY 1966

Summary

Background

The goals of engineering education have been examined from time to time and are currently the subject of an extensive national study. While meaningful discussion is being generated by the studies currently underway, there is an essential source of information which is continually overlooked or measured only indirectly. This information could be obtained by a detailed examination of the differential impact of the learning process for each student; the focus of attention should be on the identification of the variables which determine this impact. At present, the only measure of differential learning we have is a final grade. There is a wide variety of evidence that grades often hide more than they reveal.

Objectives

1. The intent of this research is to develop techniques for assessing various aspects of a student's performance in specific classes. Psychologists for the last half century have developed both a theory and a methodology for the objective evaluation of various aspects of human behavior. The fruits of this past research have in general not influenced the behavior of most teachers.
2. In order to demonstrate the need for paying more attention to a wide range of student behavior, the utility of the traditional cumulative grade point average is examined.

Procedure

Two different strategies were employed in this study. The first was a multivariate correlational study of grading practices. The second strategy

involved the use of an observer in a wide variety of engineering classes and the development of a variety of assessment devices.

A. Multivariate Correlational Study of Grades

Two classes from the School of Engineering were chosen for this study. One class consisted of all those students who entered in 1961 and graduated in 1965. The other class is made up of all those students who entered in 1963 and were still in engineering as of May 1966.

For all these students we had available their scores on a wide variety of psychological scales. They had taken these tests as part of a routine battery of tests administered to all entering freshmen.

For all men in both these classes we had recorded all their individual grades in all courses they had taken. These grades were then grouped according to principles of classification based on similarity of course content. We were then able to compute correlations between all combinations of grade classifications and all other measures of psychological traits.

B. Techniques for Evaluating the Learning Process in Engineering Education

Three separate courses--Dynamics, Design, and Introduction to Electrical Engineering--were chosen for study. These courses represented a broad range of course structures and course content. The primary intent of this research was to observe and record many facets of the student's behavior which had a bearing on his learning. Two facets of this behavior were given special emphasis: the student's general problem-solving strategy and the patterns of communication between student and teacher.

Results and Conclusions

The main report is divided into six sections and we will report the results and conclusions from each section. Then a brief restatement of the major conclusions will follow.

Section 1--Grading Practices and the Student's Motivation to Learn

An assumption underlying the use of the cumulative grade point average is that it is an accurate reflection of the student's academic performance. The ubiquitous use of this measure requires that we be very clear about what it does and does not reflect. The undergraduate curriculum in engineering is made up of many diverse segments, and the evidence presented in this section suggests that mastery of one segment is no assurance of mastery in another. This point does not deny the significant positive relationship which does exist between the different sectors. Instead, the intent is to focus on the large part of the variance which is still unaccounted for.

This focus can lead to examining some aspects of the teaching-learning process from a new perspective. The evidence suggests that a student does not work at a uniform level of performance in all courses. Perhaps this is a reality of human nature which we do not openly admit. Instead, each professor approaches his course with the view that he is presenting his material to optimally motivated students. This automatically builds in a conflict between the instructor and at least some of his students. The student has the choice of meeting the expectations of the instructor or being penalized by a low grade.

Perhaps we should work on the problem of how to create optimal motivation for all students in all courses. Some of the problems inherent in this approach will be examined in other sections of this report. At this point we are particularly interested in examining some aspects of the Stanford students' experience with the existing curriculum.

We have seen that aptitude is not significantly related to performance. In part, this can be understood to be a result of the high but narrow range of talent present among the Stanford students. Even though the narrow range of talent will reduce the possible correlation, it is also a fact that a student's aptitude has become less important in determining his current academic success than his previous academic success in high school.

What are the consequences of a student's finding that the skills upon which he has previously relied for success are no longer so trustworthy? We can come up with several lines of thinking which may provide some answers.

Some students will find this new situation very frustrating. They will, therefore, respond in accord with the methods they have previously developed to handle frustration. We can see this operating in our finding that students with a well-developed sense of responsibility achieve higher grades than students with less responsibility. On the surface this makes a good deal of sense.

In the School of Engineering we would hope that such personality characteristics as "responsibility" would be related to performance. As a professional engineer, responsibility will be a key ingredient in later success. When we look more carefully, however, at the meaning of the scale we find that there is an optimum level of responsibility. Beyond that level, the person would no longer be considered responsible in the positive sense of the term. Instead, we would begin to think in terms of someone who is over-cautious, unimaginative, and narrow in his ability to view problems.

We have a little further support for this line of speculation when we find that there is a negative relationship between academic performance and measures of self-acceptance and comfort in dealing with others. Another strand of evidence comes from the general lack of relationship between the Guilford measures of creativity and most academic areas.

We have been suggesting that some students do well because they grind away at all courses, not out of genuine interest but rather through a belief in the value of perseverence. Other students make the conscious decision that they will work hard in some courses because of the intrinsic worth to them and take the consequences of not working hard in other courses.

The curriculum and the associated grading practices as they are now conceived and put into practice have certain undesirable consequences. The pressure to do well forces some students either to deny or not develop their own intrinsic interests. Instead, they choose to meet the demands of an unrelenting faculty for work which often seems devoid of significance. In addition to learning the content of the courses, these students are also trained to be obedient and uncritical.

Other students consciously decide or are unconsciously forced to be more selective in their performance. While it is true that these students are being forced to make mature decisions about how they will use their time, it is also true that they are being punished for exercising this judgment.

There is, of course, still another group of students who do extremely well in nearly everything because of a combination of high ability and strong intrinsic interests. While in the minority, there are enough of these to justify maintaining the status quo. Viewed from one perspective, these students protect the faculty from coming to grips with the reality of how most students function.

The cumulative grade point average has become a barrier to understanding the academic behavior of students. Our intent is to get beyond this barrier by assessing what actually goes on in the classroom.

Section 2--Toward the Development of an Ideal Problem-Solving Strategy

The problem-solving behavior of the students was observed periodically throughout the school term. They volunteered to work individually on their homework problems, which constituted new material, in the presence of the researcher. While they attempted to solve the problems, they were required to verbalize as freely as possible what they were doing. In addition, the observer asked questions when clarification was needed. The following problem-solving strategy evolved. No single student incorporated all the steps; that is, the listing is an amalgamation composed of procedures contributed by several students. The steps clearly are not independent; successful handling of later steps usually requires completion of those preceding.

1. Read the pertinent section of the text thoroughly. Beginning at this point, knowledge of--or at least acquaintance with--preceding material is presumed. Usually, for each problem there were two to five pages that were directly related to its solution. This material had to be understood if following steps were to be tackled with any substantial success. Often, more than one reading was necessary; "skim" reading was useless.

2. Work through the sample problems. Texts usually contain illustrative problems helpful in conveying understanding of the content and in solving the problems at the end of the chapter. However, thorough working-through of sample problems was--in the short run, at least--time-consuming and often neglected.

3. Carefully read and define the problem. This was almost invariably a major stumbling block. Problems often appeared vague, especially if the new material was not fully understood, as was usually the case. The problem typically required several re-readings at various stages in its solution.

4. Draw a diagram of the problem, indicating the direction of forces. A correct physical impression, being able to visualize what was taking place, was a valuable aid to solution.

5. Know or look up appropriate formulas. Usually it was necessary to derive additional formulas by working from general to specific equations.

6. If possible, arrive at an intuitive answer. This was labeled by one student as the "ballpark approach"; that is, attempting to get a quantitative and/or qualitative idea of the problem that was, at least, in the right ballpark.

7. Try to apply the techniques of a sample problem. This was characteristically only partially successful, as the methods illustrated in the examples often did not directly generalize to the problem at hand.

8. Continually check the work as it proceeds. The time-consuming and demoralizing effect that an error in calculation or algebra could institute made this a crucial concern.

9. See how it comes out.

Following these steps did not guarantee success. When the correct solution did not appear, or a point of blocking occurred, students began to retrace their steps. Particular emphasis was placed on a re-reading and redefining of the problem. Often an accurate diagram, indicating understanding of the forces involved, seemed essential. Therefore, if the student was stumped, he examined and if necessary re-drew his diagram. After starting virtually from scratch, the problem was re-worked.

If an appropriate solution still was not obtained, the students characteristically fell back on another hierarchy of responses. All of them made use of break periods, ranging in time from five to thirty minutes. During their breaks, the students tried to engage in activities totally removed from study; for example, playing a quick game of basketball. Returning fresh to the problem, they were often able to figure it out. Occasionally, sleeping on a problem seemed to make the solution easier in the morning.

Many students collaborated with other class members. Trading of solutions, joint study "dates," and other forms of mutual assistance were common, and hopeful, at least in the short run. The lone wolf was at a distinct disadvantage and his scores on the problem sets were usually slightly lower than those of students who collaborated.

Finally, if all else failed, the student would turn to the professor for assistance. A few minutes at the beginning of each class were devoted to questions on the assigned problems and were usually sufficient to clear up immediate difficulties.

There are several observations which come out of this first encounter with the learning process in engineering education. They are based on working with the students on their problem-solving and also observing the general approach of the instructor. There seemed to be a great emphasis on how to do a given problem rather than focusing on those elements of the problem which might be generalized to a whole class of problems. This led to students copying everything the instructor put on the blackboard, but did not necessarily encourage them to think.

This emphasis on getting the job done is certainly a valuable part of the engineering profession. It may not, however, be the most appropriate emphasis in the training of engineers.

Section 3--Report on a Course in Engineering Design

One purpose of the survey of Engineering 9 was to determine the effectiveness of a questionnaire in opening channels of communication between the students and instructors. The degree of openness in response and the enthusiastic participation of both students and instructor indicates the potential usefulness of the technique. A questionnaire has several advantages from the students' viewpoint: it is fast, yet permits open-ended comments; it is anonymous (or could be); and it does not demand face-to-face confrontation with a possibly threatening professor. For the instructor, such an instrument is easy to prepare and administer, provides an overview of the class's progress and difficulties, and may supply some helpful teaching advice. To the benefit of student and instructor, a questionnaire may serve as an "introductory" mechanism, facilitating personal contact. Several students, for example, expressed surprise, relief, and pleasure that their opinions were being taken into account by the instructor.

If the students who are experiencing difficulties in any course are to be helped, they must be convinced of the instructor's availability. Perhaps the implementation of weekly or biweekly requests for the students to evaluate the course and their progress is a step in the right direction.

Concentrating on the students alone, however, does not seem sufficient. The instructors must feel that such contact is useful and rewarding and, furthermore, must be comfortable in what may be a relatively new role. An instructor may find it necessary, for example, to act not merely as an importer of knowledge, but as a counselor as well. It is even conceivable that an instructor and a student, by working together, may come to the conclusion that a student should leave engineering. For a student who is in the process of making such a decision, the support of an understanding faculty member can be extremely helpful. Similarly, for the student who decides to persevere, the backing of an interested professor may make the difference between success and failure.

Returning to the discussion of Engineering 9, the data make possible some tentative conclusions and suggestions. Within the context of a course which teaches the tools of descriptive geometry, it is very difficult to "inculcate the philosophy and methodology of design." A great many students perceive the course in terms of drawing, rather than design. Such an interpretation is not without justification, as a good deal of time is focused on the techniques of drawing. Elements of design, conceived in terms mentioned above, are present but not to the degree hoped for by the instructors.

Students in a course such as this are confronted with a confusing set of goals. Mastery of the technical skills of drawing is set up as one requirement. Yet many students see this as conflicting with some of the broader issues that are touched on in the course. Inadvertently the student who is more task-minded and meets the explicit requirements of the course will be more highly rewarded than the student who wants more challenging problems and thus remains unmotivated.

The implementation of a system of written feedback to the instructor permitted some expression of student attitudes. This is a valuable first step but students also need to have these attitudes recognized in terms of specific changes in course content. The issue of change in course content is both complex and important. The needs of the student cannot adequately be met by considering only one course but require an evaluation of the intended goals of the entire curriculum. This is beyond the scope of this study, but some of our conclusions will have a bearing on this topic.

Section 4--Differential Effectiveness of Small Problem-Solving Sessions

Students were asked to describe the quality of their problem-solving sessions on an open-ended questionnaire. They were also asked to rate their instructors on a standard semantic form of the semantic differential. There were sharp and consistent differences between three separate classes. There was a strong positive relationship between a student's attitude toward the class and his attitude toward his instructor. However, there was not a significant difference in the grades achieved by the students in the different classes.

There is usually a plea for having excellent instructors in the undergraduate curriculum. There is also some evidence that students can agree about the dimensions which characterize a good teacher. Students state that they enjoy the course more when they have good instructors. Do they also work more effectively and learn more? This is clearly the important question and no straightforward answer is available.

Part of the reason we don't know is the result of the very issues we are discussing in this report. Too often teaching is thought of only in terms of what the teacher does while actually teaching. If evaluation is not considered a vital element in the teaching process, then there are at least two serious consequences. Not enough thought is given to what is being measured and the students' reactions to the measurement process are often disregarded. Learning and getting good grades are too often distinct processes because teaching and evaluation are often separately conceived.

Section 5--Responses to a Problem-Orientation Questionnaire

This initial instrument attempts to measure some attitudes and behaviors of engineering students related to the solution of assigned problems. The items are aimed at eliciting the students' reactions to problem sessions and session instructors, the problems themselves, and problem-solving methodology.

The questionnaire was administered to a sample of 40 students from a course in introductory electrical engineering. Subjects were predominantly juniors and seniors; no freshmen were taking the course. There were representatives from the electrical, mechanical, industrial, and civil disciplines of engineering. The questionnaire was included among other measurements of student attitudes.

A majority of the students considered the problem sessions, which were conducted by the lecturer and two assistants, all Ph.D.'s, to be of some use. Almost unanimously, however, the students thought that the success of a problem session depends largely on the instructor. It is worth noting that students in the session taught by the lecturer, who was rated as an excellent teacher, had consistently better impressions than those instructed by the teaching assistants.

Half the students wish, for example, that grades were not so dependent upon their ability to work problems, and 70 per cent admit that they sometimes get sick and tired of doing nothing but problems. Yet the great majority are responsible about getting assigned problems done on time. It should be noted, however, that hardly anyone does additional problems for self-edification. Apparently, the interest in solving problems is satiated for most students by assigned work, and spare time is spent on other activities.

The importance of problem-solving for examination purposes is fully recognized, although not with a great deal of relish by many. Almost all students review problems before a test. On tests where speed of problem-solving is a major factor, three-quarters of the students harbor feelings of resentment, usually expressed in terms of "If I had had more time I could have done much better." Clearly, examinations which emphasize speed alienate a good many students, and perhaps their utility as determinants of grades should be reconsidered.

Most students share a common problem-solving behavior pattern. Although study breaks are widely employed, persistence appears to be a typical characteristic. Inability to solve an assigned problem results in real frustration for half the students, but hardly any lose sleep over it. Working through the sample problems, a highly recommended technique, is adopted by very few, primarily, it is claimed by the students, because of time pressure. Probably the only way to encourage students to do the sample problems would be to prove their time-saving efficacy. The almost unanimous belief that a general problem-solving strategy exists points up the necessity for the development of and instruction in an optimal approach to problems.

Section 6--Some Innovations in Teaching a Section in Electrical Engineering

In an attempt to investigate the effectiveness of some innovations in teaching techniques, a small section of an electrical engineering course was selected. The class was composed of eight volunteer students from a larger class of about sixty students. They were informed that some informal experimentation in teaching methods would be tried, but the class would cover the same amount of material as usual. The instructor was a Ph.D. candidate on his first teaching assignment and very amenable to trying out various approaches.

From the earlier observations of other classes, it was felt that communication between teacher and student could be improved. At the beginning of the quarter this was briefly discussed with the entire class. All agreed it would be desirable to work at improving communication. One approach was to reserve a few minutes at the end of each class session for student evaluation of the presentation of material and other classroom activity. These notes were given the instructor at the end of each week.

The instructor was asked to facilitate communication by organizing the presentation of his content in such a way that there would be natural stopping points. At such points he would pose a question about the material just presented and ask all members of the class to write their answers. After a few minutes for each student to think about the question, there would be a general discussion of the correct solution.

From our work in other courses it became clear that "problem-solving strategy" was an inherent part of the curriculum. It was never emphasized, however, in a manner which made the student aware of the process. Problem-solving strategy seemed to be taken for granted or was imbedded in the content of the course. Our previous observations suggested that the problem-solving methods of many engineering students were quite disorganized. Students rarely approached their typical problems with any definite plan of procedure.

It seemed desirable, therefore, to make the discussion of problem-solving strategy an explicit goal of the course. Students were asked to discuss their procedure for solving particular problem sets. This statement included a time-allotment schedule: each student was to indicate the time spent in initial thinking about the problem, including efforts which led to incorrect results.

After the first problem set was turned in, the instructor led a general discussion about problem-solving methods. The need for spending more time thinking before plunging in was repeatedly emphasized. Along with this, was emphasis upon having a clear plan for systematically attacking a problem. For each problem set turned in to the instructor, he would make comments about the student's problem-solving strategy. The instructor in his written comments would raise questions about why the student took one approach rather than another.

In an effort to focus on these strategies in the classroom, the instructor's questions were so framed as to illustrate the general approach. For example, students were sometimes asked to anticipate the next step on the basis of previous information. In the presentation of a circuit system, for instance, students would be requested to provide some of the appropriate components.

Most of the students in the course felt it was very worthwhile, both in terms of what they learned and from the perspective of an interesting adventure in learning. The long-heard cry for more teacher-student interaction was satisfactorily met. Nevertheless, some students were uninterested and could not be drawn into the learning process. We mention this only to illustrate the point that some students, at a given point in their lives, will not be open to learning.

Of greater significance is the varying degree of dissatisfaction that students who did well in the course felt with its general philosophy. Here students were not complaining about how things were being done. We know that overall they were fairly well satisfied. Instead, they were raising questions about <u>why</u> they were being expected to learn this way in the first place. The large amount of material and necessary memorization that went with it were not congruent with their wishes.

We have been concerned with examining the effects of encouraging more student-teacher communication. Overall, this seems both desirable and beneficial to the learning process. It does seem to open Pandora's box, however, because the students begin to raise fundamental questions about the aims of a given course and the goals of the undergraduate curriculum.

Conclusions and Implications

Teaching is one of the major functions of the faculty. The goals of these teaching efforts can be described at different levels of analysis. At one level the primary goal of the instructor is the presentation of the specific content of the course. It has been the intent of this report to demonstrate that the methods used in presenting the content of the course and the methods used for evaluating a student's mastery of the course content have far reaching consequences. The full extent of these consequences can only be understood if we move to another level of analysis. Here we have to examine the goals of the entire curriculum. Only then can we examine what contribution a given course is making toward that goal.

It is generally agreed that mastery of the content of the curriculum is only part of the larger goal of the curriculum. The other parts are a little more elusive when we try to define them and even more elusive when we try to implement them. The following is one statement of these larger goals: "We must encourage our students to learn to think independently, evaluate their own and others' work with high critical standards and be free enough to see creative alternatives. We must also encourage in our students the motivation to continue learning and to actively pursue their own intellectual curiosity. We must also develop in our students an awareness of the complexity of the technological revolution that is occurring in our society and an awareness of their own individual role in such a society."

While such goals may be stated differently there is an underlying theme which would represent a consensus. Our expectations for a student's development go well beyond the accumulation of facts or even the techniques for solving complex yet well-defined problems. In light of these larger expectations we can examine the consequences of teaching in any given course and furthermore examine the consequences of the current structure of the curriculum. In this study we have explored several questions which have relevance to these issues and have arrived at the following conclusions:

For a narrow range of high ability students there is little or no correlation between academic performance and intellectual aptitudes. Instead a variety of variables that are associated with motivation and attitude account for more of the variability in student's academic performance. There is some evidence which suggests that attitudes having to do with perserverence rather than creativity are highly correlated with success in the engineering curriculum.

Although creativity and flexibility are recognized as important ingredients in the problem-solving orientation of engineers, there is little evidence of this being a major focus of attention in the training of engineers. Even where an instructor may reveal some of these characteristics in his teaching, there is a lack of follow through when it comes to evaluating the student's performance. A wide variety of factors make the student more responsive to what he is being taught. This inadvertently leads students to focus on learning in a passive manner rather than actively pursuing the intellectual challenges of the course material.

By instituting a variety of means for students and instructors to communicate with each other, many of the larger goals of the curriculum can be made relevant to any subject. Evaluation of the learning process becomes something that both teacher and student engage in and thús share in a common enterprise.

Bibliography

There are ten references listed in the final report.

Publications

Hatton, John, "Toward the Development of an Ideal Engineering Problem-Solving Strategy," J. of Engineering Education (in press)